PHYTOTOXICOLOGY ASSESSMENT SURVEYS IN THE VICINITY OF INCO LTD., PORT COLBORNE - 1985, 1986

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Introduction and Review of Previous Results

The Phytotoxicology Section has conducted surveys of nickel contamination of vegetation and/or soil in the vicinity of the Inco smelter, Port Colborne, annually since 1972. Significant nickel injury to street maple trees in Port Colborne was documented in earlier surveys, but in recent years (since 1980) visible nickel injury to street trees has declined in severity to the point of non-significance. This reduction in injury has been attributed to a reduction in emissions from Inco. Nevertheless, concentrations of nickel (Ni), copper (Cu) and cobalt (Co) measured in both tree foliage and moss bags in the vicinity of the refinery, although reduced, have continued to be elevated relative to control data. Phytotoxicology monitoring of sulphur and chlorine contamination from Inco in recent years has not shown the presence of significantly elevated levels of these elements in tree foliage or moss bags near the refinery.

The Inco, Port Colborne refinery was shut down from June 1982 until February 1983. Concentrations of Ni, Cu and Co in moss bags and maple foliage collected during shut-down were significantly reduced.

In 1983, levels of Ni and Cu in maple foliage in the vicinity of the Inco refinery in Port Colborne increased from those measured in the shut-down year of 1982, but they were similar to levels found in 1980 and 1981, and were lower than 1977 levels. Cobalt levels in tree foliage increased slightly from 1982 to 1983, but remained considerably lower than in 1977, 1980 or 1981.

In 1984, Ni concentrations in tree foliage were lower than measured in any previous operational year. However, Cu levels increased to levels similar to those found in 1977. Cobalt concentrations increased slightly from 1983, but remained lower than measured in any year prior

to the shut-down year of 1982. High levels of Co and especially Cu in moss bags exposed during mid-May to mid-June 1984, immediately downwind of the Inco stack, indicated that unusually large emissions of these elements from Inco had occurred during this period.

Methods and Observations

On September 20, 1985 and again on September 24, 1986, samples of maple foliage were collected from 22 stations in the vicinity of the Inco, Port Colborne refinery (Figure 1). On both of these dates, tree foliage was examined for symptoms of nickel toxicity. No foliar injury ascribed to nickel toxicity was observed, although a number of natural conditions (e.g., scorch, leaf roller, insect chewing, leaf gall, fungal infection, fall senescence) were present at various locations.

Moss bag monitoring also was conducted near the refinery during 1985 and 1986. Sphagnum moss bags were exposed at 13 stations around the perimeter of the Inco property (Figure 2) during June to October of 1985 and April to September of 1986.

Tree foliage and moss bag samples were processed in the Phytotoxicology laboratory and were submitted to the MOE Laboratory Services Branch for analysis of nickel (Ni), copper (Cu) and cobalt (Co).

Results

Tree Foliage Results

Tables 1 to 3 give levels of Ni, Cu and Co, respectively, in unwashed tree foliage collected near Inco for the years 1977 and 1980 through 1986.

Nickel

Process changes which came on stream in June of 1984 would have been expected to result in a significant reduction in metallic emissions.

Indeed, Ni levels found in the 1984 survey were substantially lower than in 1983 (Table 1). Levels of Ni found in 1985 were somewhat higher than in 1984. Levels found in 1986 were less than in 1985 and were the lowest operational levels of any year since Phytotoxicology Section surveys commenced.

Although Ni levels in maple foliage near Inco have generally been declining since 1977, higher than "normal" concentrations of Ni (>7 µg/g urban, >5 µg/g rural) were measured at 16 of 21 stations in 1986, with the highest concentration (160 µg/g) being 23 times higher than the Phytotoxicology urban guideline. However, not all of the foliar contamination is due to direct aerial emissions from Inco. Soil re-entrainment and root uptake also contribute to Ni concentrations in tree foliage.

Figure 3 shows that average foliar Ni levels near Inco have been generally decreasing since 1977.

Copper

Average copper levels in maple foliage near Inco decreased from 1984 to 1985, and again from 1985 to 1986 (Table 2). However, the 1984 average level was substantially higher than the three prior operational years (1980, 1981, 1983). Regardless, the Cu levels found in 1985 and 1986 were lower than any found previously in an operational year. In 1986, 2 of 21 stations had copper concentrations exceeding the "upper limit of normal" guideline of 20 µg/g, with a maximum level of 24 µg/g. For comparison, in 1984, 10 of 22 stations exceeded the upper limit of normal, with a maximum level of 80 µg/g.

Cobalt

Average cobalt concentrations in unwashed tree foliage near Inco (Table 3) decreased from 1984 to 1985, and again from 1985 to 1986. However, as with Cu levels, cobalt levels in 1984 were higher than in 1983. Cobalt levels in 1983 and 1985 were the same; 1986 levels were the lowest found in a Phytotoxicology Section survey, in an operational year. Cobalt levels found since 1982 have remained considerably lower than in any prior year (Fig. 3). In 1986, levels of cobalt were higher than "normal" (>2 µg/g) at 4 of 21 stations, with the highest measured concentration being 7 µg/g.

Moss Bag Results

Tables 4 to 6 present concentrations of Ni, Cu and Co, respectively, in Sphagnum moss bags exposed for approximately 30-day periods during 1985 and 1986 at 13 stations around the perimeter of the Inco property (Figure 2).

Nickel

Nickel levels in moss bags near Inco (Table 4) during 1985, and to a lesser extent 1986, reflected the effect of the Inco summer shut-downs. During the shut-down month of July 1985, the average nickel concentration was 99 µg/g versus approximately 230 to 600 µg/g during operational months.

The 1986 summer shut-down period at Inco was June 2 - August 10 for the main operation and June 15 - August 17 for the cobalt area. The shut-down effect on moss bag nickel levels is not as well defined in the 1986 data as the three previous years. Levels did decrease during the shut-down period but did not increase after.

When data for all exposure periods are examined, the highest overall Ni accumulations occurred at Station 139, downwind (NNE) of the stack. This occurred for all four years, 1983 to 1986. During 1986, Station 139 also recorded surprisingly high Ni levels during the summer shut-down. The reason for this anomalous result is unknown. Given the overall trend toward decreasing contaminant levels, it is not considered a significant finding.

Figure 4 shows that year-to-year changes in mean moss bag nickel concentrations correspond well with nickel levels in unwashed maple foliage. This result also holds true for the two other metals examined, copper and cobalt.

Copper

Copper concentrations in Inco moss bags (Table 5) in 1985 partially reflect the effect of the Inco summer shut-down. The 1986 Cu results, as with Ni, show only weak correspondence to the reported shut-down period. A complicating factor may be that the shut-down period in 1986

encompassed portions of three of the five moss bag exposure periods. In general, for both 1985 and 1986, the changes in moss bag copper levels from one exposure period to the next are similar to the changes in nickel levels.

In 1984, copper levels in moss bags were very high for the mid-May to mid-June exposure. No such unusually high levels were obtained in either 1985 or 1986.

Cobalt

Cobalt levels in moss bags (Table 6) decreased during the summer shut-downs at Inco in both 1985 and 1986, as expected. The correspondence between moss bag metal levels and reported Inco shut-down periods appears to be better with cobalt than either copper or nickel. This may be related to the existence of a separate cobalt refining operation.

SUMMARY

In the years 1984, 1985 and 1986, average levels of Ni in maple foliage in the vicinity of the Inco refinery in Port Colborne were substantially lower than in previous operational years. In 1986, Ni concentrations in tree foliage were the lowest ever recorded (with the exception of the shut-down year of 1982). Nevertheless, Ni concentrations in 1986 foliage samples exceeded the Phytotoxicology Section "Upper Limit of Normal" guideline at 16 of 21 sampling stations.

Copper and cobalt levels in tree foliage decreased from 1984 to 1985 and again in 1986. The average 1986 tree foliage copper and cobalt concentrations also were lower than measured in any previous operational year.

Average concentrations of Ni, Cu and Co in Sphagnum moss bags exposed around the perimeter of the Inco refinery in 1986 were the lowest since such monitoring began in 1983.

Changes in moss bag contamination levels closely mirrored the tree foliage results.

TABLE 1 - Nickel Concentrations (µg/g, dry wt.) in Unwashed Maple Foliage (facing source) Collected in September of 1977 and 1980 - 1986 in the Vicinity of Inco, Port Colborne.

Station No.	Street Location	Distance (m) and Direction from Inco Stack	Ni Concentration 1977	1980	1981	1982	1983	1984	1985	1986
1	105 Mitchell	400 NW	181	136	122	18	83	24	24	15
2	15 Kinnear	365 NW	167	193	215	18	233	28	42	24
3	Lake Rd. & Welland	420 W	13	40	32	12	90	21	31	18
4	Louis near Davis	640 NNW	178	134	140	18	120	45	56	27
5	292 Fares	800 NNW	92	50	130	12	65	22	30	17
6	279 Welland	1025 NNW	71	42	28	6	24	11	14	18
7	29 McRae	900 N	280	42	134	11	110	60	130	64
8	129 McRae	1150 N	112	34	42	9	50	34	46	26
9	43 Colborne	960 NNE	265	252	310	40	163	240	185	120
10	222 Christmas	1450 NE	200	218	107	18	162	76	125	30
11	Killaly & Snider	1900 NE	148	125	87	15	73	56	124	45
12	Babion Rd.	3700 NE	102	23	20	5	22	21	28	3
14	Reuter Rd.	920 E	55	42	26	15	22	21	18	11
15	Lorraine Rd.	2100 E	46	25	12	7	10	7	8	5
16	Weaver Rd.	3000 E	23	20	13	3	9	4	6	5
17*	Lake Rd.	230 SSW	440	134	107	35	167	73	89	160
18	Killaly & Lorraine	2500 ENE	90	33	29	6	27	19	23	11
19	3rd Conc. & Miller Rd.	6500 NE	27	20	10	2	6	6	8	3
20	Pinecrest Rd.	4500 E	15	12	10	7	14	8	2	2
21	White Rd. & 2nd Conc.	5700 NE	122	41	50	9	33	12	30	14
23	3rd Conc. & Ramey Rd.	5400 N	19	13	10	2	6	4	6	-
24	146 Davis	360 NNW	-	294	600	35	300	86	70	38
Mean Concentration			131	87	101	14	81	40	50	31

* Choke cherry foliage collected (basswood in 1986).

- Phytotoxicology Section upper "limit of normal" of nickel concentrations in unwashed tree foliage: 7 µg/g (urban), 5 µg/g (rural).

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TABLE 2 - **Copper Concentrations (µg/g, dry wt.) in Unwashed Maple Foliage (facing source) Collected in September of 1977 and 1980 - 1986 in the Vicinity of Inco, Port Colborne. Street locations of sampling stations are given in Table 1.**

Station No.	Distance (m) and Direction from Inco Stack	Cu Concentration 1977	1980	1981	1982	1983	1984	1985	1986
1	400 NW	21	19	23	16	18	28	22	15
2	365 NW	27	17	25	9	26	18	16	12
3	420 W	15	9	8	6	13	12	9	9
4	640 NNW	14	24	18	12	26	24	24	12
5	800 NNW	22	16	15	12	23	17	16	12
6	1025 NNW	22	15	12	5	10	9	10	9
7	900 N	53	12	14	7	17	18	18	12
8	1150 N	37	15	10	9	16	22	10	8
9	960 NNE	50	36	34	12	33	80	23	17
10	1450 NE	37	32	17	11	36	46	22	13
11	1900 NE	33	24	25	9	21	33	20	12
12	3700 NE	25	13	11	7	10	26	17	10
14	920 E	17	12	23	8	11	43	12	14
15	2100 E	16	9	14	11	9	11	9	7
16	3000 E	6	11	6	13	11	17	9	10
17*	230 SSW	46	11	9	5	15	12	12	23
18	2500 ENE	26	11	12	7	10	21	18	12
19	6500 NE	8	10	8	6	7	14	9	10
20	4500 E	11	14	12	6	12	13	6	4
21	5700 NE	25	24	29	12	11	18	20	24
23	5400 N	6	8	7	4	8	9	8	-
24	360 NNW	-	16	29	9	22	22	14	10
Mean Concentration		24.1	16.3	16.4	8.9	16.6	23.4	14.7	12.1

* Choke cherry foliage collected (basswood in 1986).
- Phytotoxicology Section upper "limit of normal" copper concentrations in unwashed tree foliage: 20 µg/g (urban and rural)

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TABLE 3 - Cobalt Concentrations (µg/g, dry wt.) in Unwashed Maple Foliage (facing source) Collected in September of 1977 and 1980 - 1986 in the Vicinity of Inco, Port Colborne. Street locations of sampling stations are given in Table 1.

Station No.	Distance (m) and Direction from Inco Stack	Co Concentration 1977	1980	1981	1982	1983	1984	1985	1986
1	400 NW	6	4	20	1	2	4	2	1
2	365 NW	9	7	41	1	5	2	2	2
3	420 W	8	3	3	1	2	4	2	1
4	640 NNW	8	10	8	2	3	4	4	2
5	800 NNW	6	5	12	1	2	2	2	1
6	1025 NNW	7	5	3	1	<1	<1	<1	1
7	900 N	16	5	8	1	3	6	4	4
8	1150 N	8	3	2	1	1	2	1	1
9	960 NNE	15	18	19	1	5	9	6	4
10	1450 NE	13	15	2	1	5	4	4	2
11	1900 NE	12	10	2	1	2	3	5	2
12	3700 NE	7	3	3	1	<1	2	<1	<1
14	920 E	3	4	2	1	<1	<1	<1	<1
15	2100 E	4	3	1	1	<1	<1	<1	<1
16	3000 E	2	3	2	1	<1	<1	<1	<1
17*	230 SSW	23	8	8	2	4	4	4	3
18	2500 ENE	6	3	2	1	1	2	<1	<1
19	6500 NE	2	2	2	1	<1	<1	<1	<1
20	4500 E	2	2	2	1	1	<1	<1	<1
21	5700 NE	6	3	4	1	1	<1	<1	<1
23	5400 N	2	<2	2	1	<1	<1	<1	-
24	360 NNW	-	13	65	1	7	21	8	7
Mean Concentration		7.9	5.9	9.7	1.1	2.2**	3.3**	2.2**	1.7**

* Choke cherry foliage collected (basswood in 1986).
**0.5 µg/g assumed where concentration <1 µg/g
- Phytotoxicology Section "upper limit of normal" cobalt concentrations in unwashed tree foliage: 2 µg/g (urban and rural)

TABLE 4 - Nickel Concentrations (µg/g, dry weight) in Moss Bags Exposed Around the Perimeter of the Inco, Port Colborne Property - 1985, 1986

Sta. No.	Distance (m) and Direction from Inco Stack	1985 Exposures					1986 Exposures						1984 Mean Concentrations for each station	1983 Mean Concentrations for each station
		Exp. 1 (June 6 - July 3)	Exp. 2 (July 3 - Aug. 8)	Exp. 3 (Aug. 8 - Sept. 10)	Exp. 4 (Sept.10- Oct. 15)	1985 Mean Concentrations for each station	Exp. 1 (Apr.10 - May 12)	Exp. 2 (May 12 - June 18)	Exp. 3 (June 18- July 18)	Exp. 4 (July 18- Aug. 25)	Exp. 5* (Aug.25 - Sept.24)	1986 Mean Concentrations for each station		
101	210 SW	250	29	-	300	193	260	260	18	39	31	122	146	329
131	210 WNW	210	65	190	200	166	150	190	36	58	45	96	153	577
132	280 NW	130	31	-	150	104	100	180	47	22	54	81	139	531
133	370 NW	-	-	-	170	(170)	170	260	110	70	52	132	161	439
134	520 NNW	51	39	100	350	135	-	170	28	27	53	70	74	313
135	590 NNW	87	76	250	610	256	240	120	-	-	240	200	169	328
136	730 NNW	110	87	95	580	218	75	240	18	23	79	87	94	245
137	740 N	340	120	380	1100	485	120	140	22	55	129	93	260	400
138	770 NNE	380	320	360	1400	615	160	130	-	-	422	237	515	731
139	900 NNE	660	-	540	1100	767	570	530	1500	670	239	702	1000	944
140	1290 NE	500	210	1100	880	672	1050	1200	310	130	167	571	628	652
110	900 ENE	28	17	-	-	22	-	34	6	-	-	20	29	42
125	900 ESE	8	-	-	-	(8)	23	-	11	-	-	17	15	14
Mean Concentration for Each Exposure Period		230	99	377	622	293 (grand mean)	290	288	191	122	137	187 (grand mean)	262 (grand mean)	427 (grand mean)

- Average nickel concentration in unexposed moss bags = 4µg/g
- Phytotoxicology Section "upper limit of normal" nickel concentration in moss bags (30-day exposure) = 13 µg/g (urban); 6 µg/g (rural)
- Results are not "corrected" for unexposed concentrations.
- Inco summer shut-down: 1985 July 1 - August 4
  1986 June 2 - August 10 (main operation), June 15 - August 17 (cobalt operation).

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TABLE 5 - Copper Concentrations (µg/g, dry weight) in Moss Bags Exposed Around the Perimeter of the Inco, Port Colborne Property - 1985, 1986

Sta. No.	Distance (m) and Direction from Inco Stack	1985 Exposures					1986 Exposures							
		Exp. 1 (June 6 - July 3)	Exp. 2 (July 3 - Aug. 8)	Exp. 3 (Aug. 8 - Sept. 10)	Exp. 4 (Sept.10- Oct. 15)	1985 Mean Concentrations for each station	Exp. 1 (Apr.10 - May 12)	Exp. 2 (May 12 - June 18)	Exp. 3 (June 18- July 18)	Exp. 4 (July 18- Aug. 25)	Exp. 5 (Aug.25 - Sept.24)	1986 Mean Concentrations for each station	1984 Mean Concentrations for each station	1983 Mean Concentrations for each station
101	210 SW	13	6	-	12	10	29	52	8	8	6	21	13	33
131	210 WNW	13	13	12	21	15	19	36	10	9	6	16	40	44
132	280 NW	11	8	-	34	18	23	50	14	8	11	21	72	36
133	370 NW	-	-	-	52	(52)	50	93	22	16	16	39	129	51
134	520 NNW	13	22	19	120	35	-	66	11	12	16	26	87	45
135	590 NNW	9	14	22	260	76	18	36	-	-	44	33	124	41
136	730 NNW	13	20	40	440	128	21	54	9	35	22	28	90	43
137	740 N	22	32	66	450	142	15	31	10	14	36	21	129	53
138	770 NNE	34	80	110	270	124	47	40	-	-	60	49	231	87
139	900 NNE	62	-	54	180	99	130	120	76	59	46	86	449	163
140	1290 NE	110	61	160	370	132	340	370	110	49	39	182	499	148
110	900 ENE	14	13	-	-	14	-	120	7	-	-	64	110	25
125	900 ESE	5	-	-	-	(5)	37	-	17	-	-	27	19	7
Mean Concentration for Each Exposure Period		27	27	60	201	65 (grand mean)	66	89	27	23	27	47 (grand mean)	153 (grand mean)	60 (grand mean)

- Average copper concentration in unexposed moss bags = 7 µg/g
- Phytotoxicology Section "upper limit of normal" copper concentration in moss bags (30-day exposure) = 60 µg/g (urban); 8 µg/g (rural)
- Results are not "corrected" for unexposed concentrations.
- Inco summer shut-down: 1985 July 1 - August 4
  1986 June 2 - August 10 (main operation), June 15 - August 17 (cobalt operation).

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TABLE 6 - Cobalt Concentrations (µg/g, dry weight) in Moss Bags Exposed Around the Perimeter of the Inco, Port Colborne Property - 1985, 1986

Sta. No.	Distance (m) and Direction from Inco Stack	1985 Exposures					1986 Exposures							
		Exp. 1 (June 6 - July 3)	Exp. 2 (July 3 - Aug. 8)	Exp. 3 (Aug. 8 - Sept. 10)	Exp. 4 (Sept.10- Oct. 15)	1985 Mean Concentrations for each station	Exp. 1 (Apr.10 - May 12)	Exp. 2 (May 12 - June 18)	Exp. 3 (June 18- July 18)	Exp. 4 (July 18- Aug. 25)	Exp. 5 (Aug.25 - Sept.24)	1986 Mean Concentrations for each station	1984 Mean Concentrations for each station	1983 Mean Concentrations for each station
101	210 SW	13	3	-	13	10	26	42	<1	3	3	15	18	10
131	210 WNW	16	4	26	23	17	29	34	2	4	12	16	19	16
132	280 NW	30	3	-	18	17	25	55	6	3	14	21	38	21
133	370 NW	-	-	-	23	(23)	25	49	5	6	14	23	40	27
134	520 NNW	11	4	8	23	12	-	14	2	2	10	7	11	12
135	590 NNW	16	5	17	34	18	13	9	-	-	39	20	24	12
136	730 NNW	23	6	12	33	18	7	12	1	2	19	8	16	10
137	740 N	27	10	18	41	24	8	7	2	3	8	6	27	14
138	770 NNE	18	18	28	51	29	17	12	-	-	14	14	44	24
139	900 NNE	29	-	27	37	31	39	33	48	23	13.	31	57	45
140	1290 NE	38	11	54	27	32	76	89	10	7	9	40	46	28
110	900 ENE	2	1	-	-	2	-	2	<1	-	-	1	2	2
125	900 ESE	<1	-	-	-	<1	3	-	1	-	-	2	1	<1
Mean Concentration for Each Exposure Period*		19	7	24	29	18.0 (grand mean)	24	30	8	6	14	15.7 (grand mean)	26.4 (grand mean)	17.0 (grand mean)

*0.5 µg/g assumed where concentration is <1 µg/g

- Average cobalt concentration in unexposed moss bags = <1 µg/g
- Phytotoxicology Section "upper limit of normal" cobalt concentration in moss bags (30-day exposure) = 6 µg/g (urban).
- Results are not "corrected" for unexposed concentrations.
- Inco summer shut-down: 1985 July 1 - August 4
  1986 June 2 - August 10 (main operation), June 15 - August 17 (cobalt operation).

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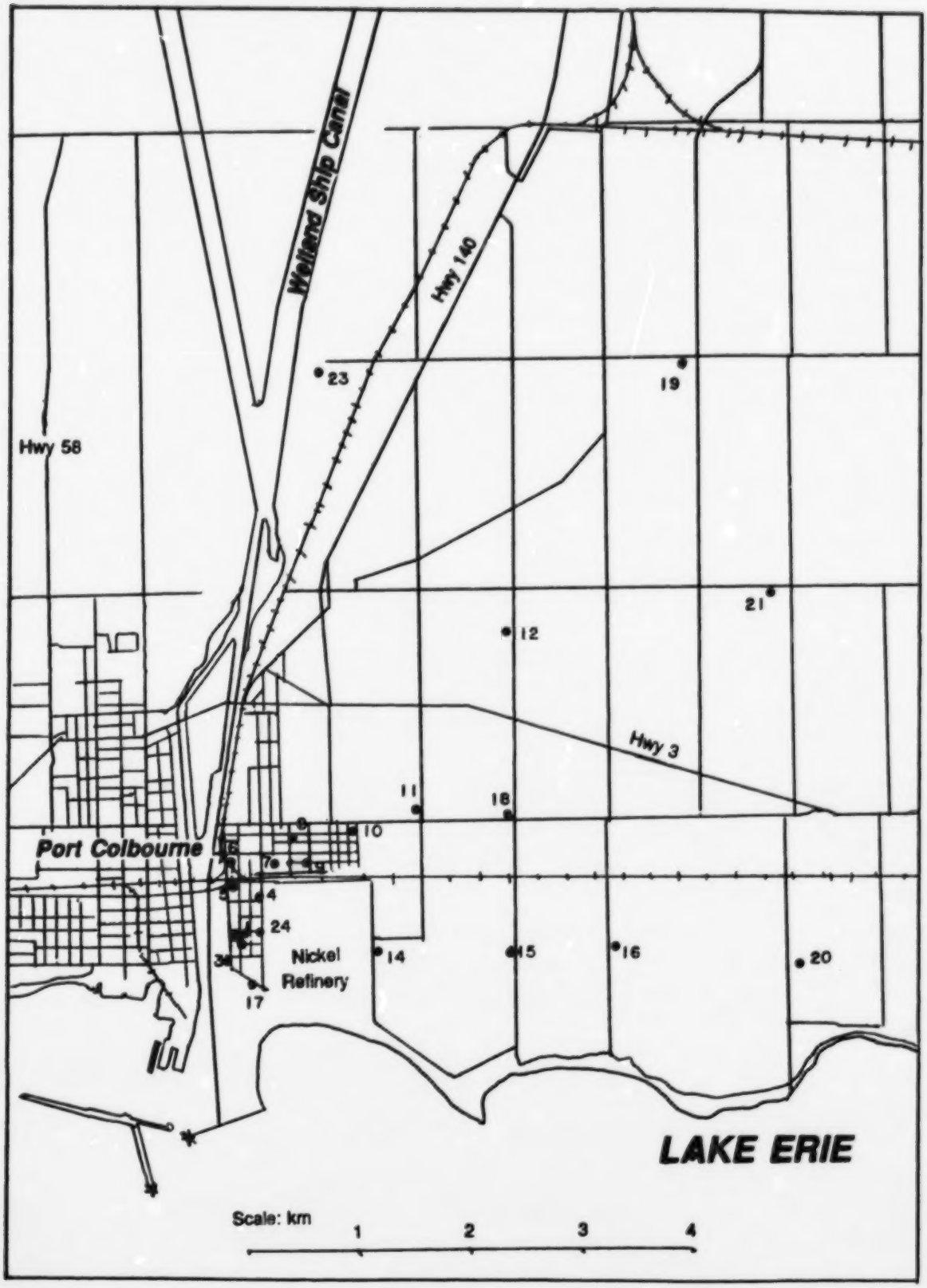

FIGURE 1. Locations of vegetation sampling stations in the vicinity of INCO, Port Colbourne 1985-1986

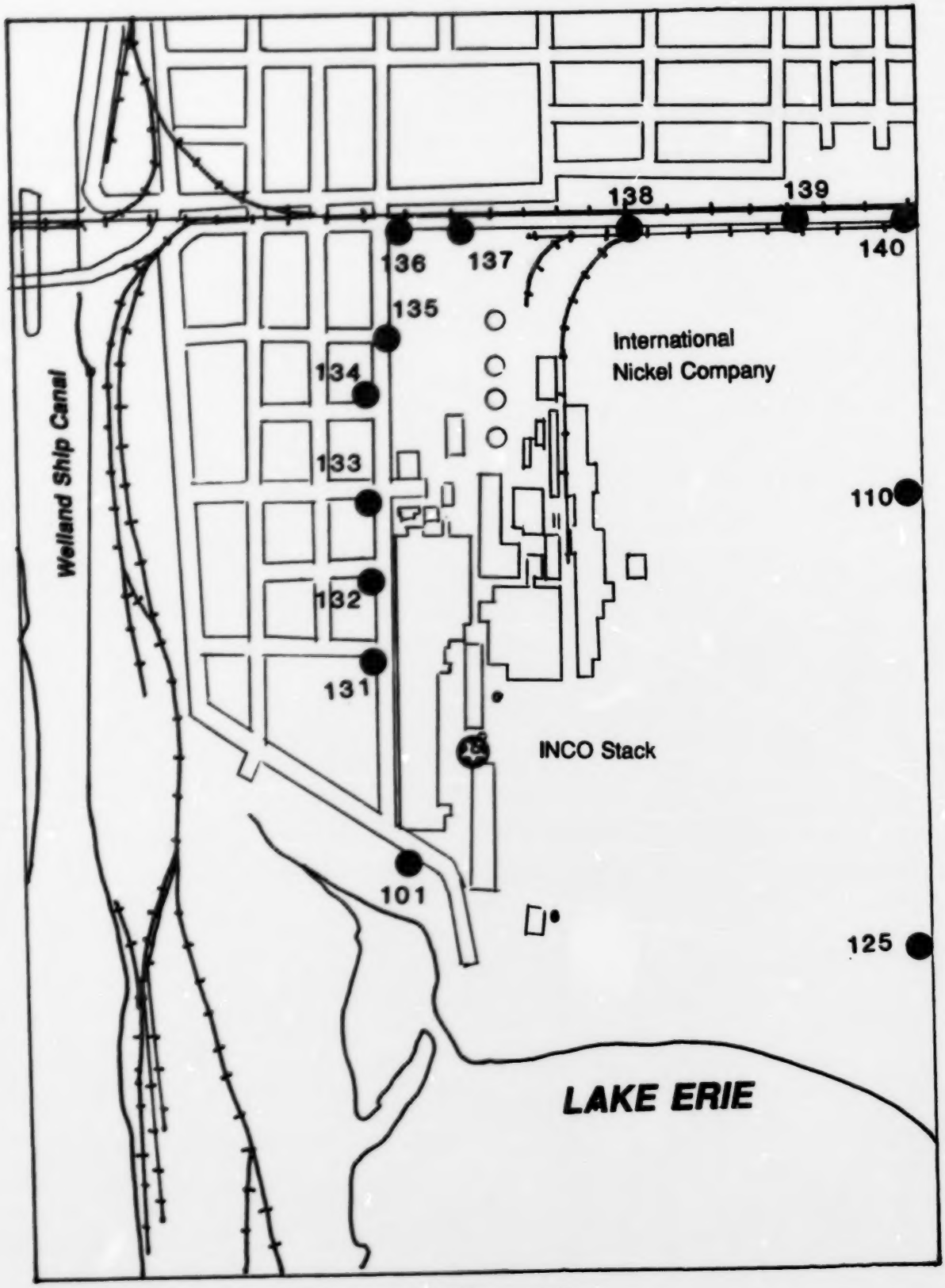

FIGURE 2. Locations of moss bag surveillance stations around the perimeter of the INCO, Port Colbourne property 1985-1986

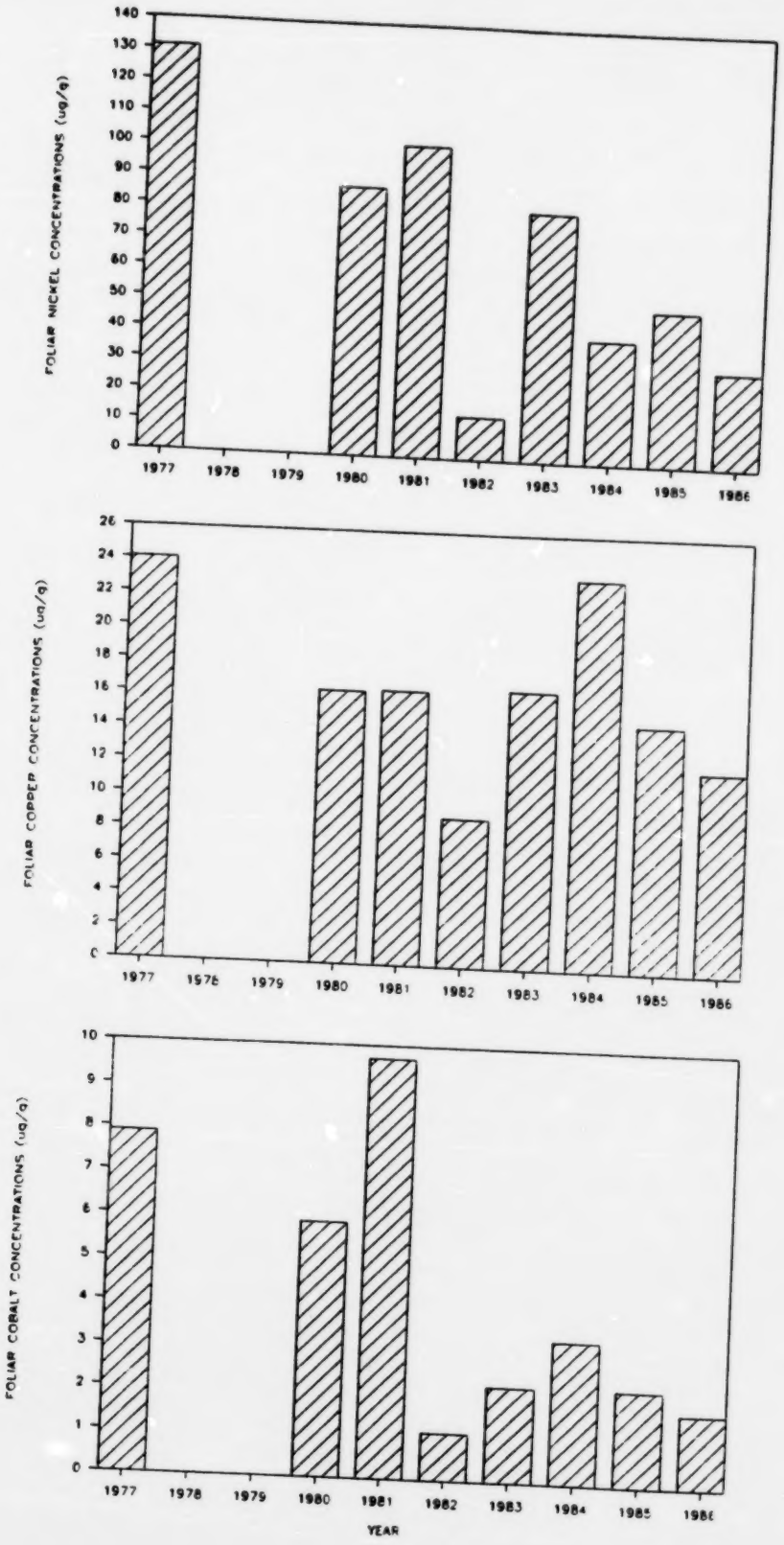

FIGURE 3. Average concentrations of nickel, copper and cobalt in unwashed tree foliage collected in the vicinity of the INCO refinery in Port Colbourne 1977 to 1986

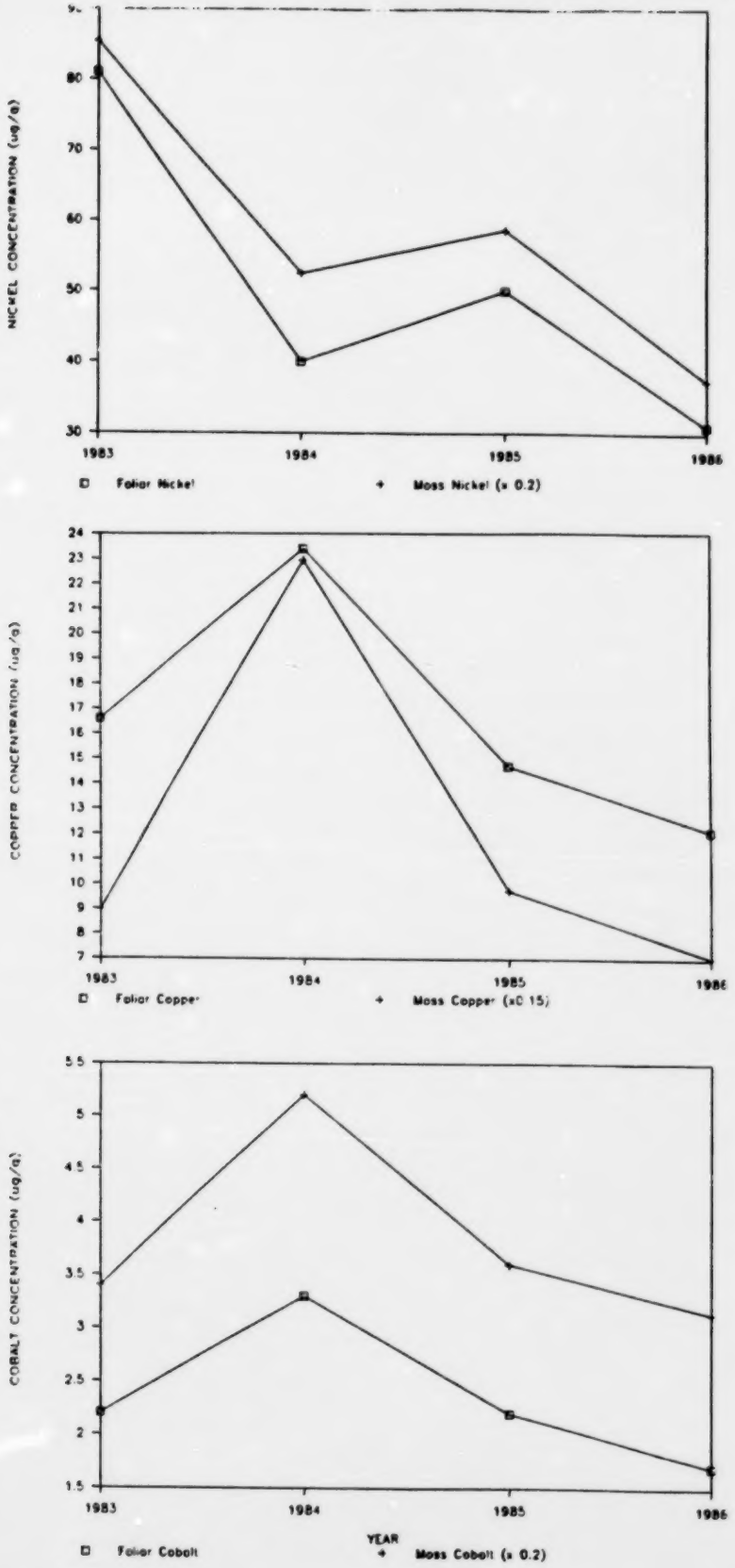

FIGURE 4. Average concentrations of nickel, copper and cobalt in unwashed tree foliage and Sphagnum moss bags in the vicinity of the INCO refinery in Port Colbourne 1983 to 1986